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Identification of Auditory, Linguistic, and Attention Systems with Task Subtraction Functional MRI

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Introduction

Although many functional MRI (FMRI) studies have demonstrated signal changes occurring between active and "resting" states, it should be possible to measure changes occurring during alternation between two active tasks that differ in a specific feature of interest. Regions showing such changes would be those participating to a greater or lesser extent in one task than in the other. If feasible, this "subtraction" technique could provide a powerful tool for the investigation of complex tasks using FMRI, by allowing controls for sensorimotor and other aspects of such tasks. We tested this method using tasks designed to activate two distinct levels of auditory processing.

Methods

Ten right-handed subjects were studied using a 1.5 T scanner equipped with three-axis local gradient and whole-brain if coils. FMRI used a gradient-ceho EPI sequence (TE 40ms, TR 3-6s, FOV 24cm, matrix 64x64, slice thickness 7-10mm). Sagittal images of the lateral convexity were obtained bilaterally. Stimuli consisted of digitized pure tones and human speech, presented using a computer playback system. Sound was amplified and delivered by air conduction via plastic tubes inserted in the ear.

A tone discrimination task was designed as a control for auditory sensory, motor, and attentional functions. In this task, subjects heard groups of 3 to 7 sequential 500 or 750 Hz tones. A button press using the left hand was required for any sequence containing two occurrences of the 750 Hz tone. A semantic decision task was used to activate semantic language networks. In this task, subjects heard spoken nouns designating animals and were required to respond to those words meeting both of two specified semantic criteria. Target words designated animals that were both "native to the United States" and "used by humans." Stimuli were matched for duration, amplitude, rate, and target frequency. The tasks differed primarily in the degree of semantic processing required:

	Tone	Semantic
Function	Discrimination	Decision
semantic association		+
sustained attention	+	+
auditory processing	+	+
motor response	+	+

Tasks were performed in a periodic manner, with 24 s task periods. Tone discrimination was alternated with rest (tone-rest) during one image series, and semantic decision was alternated with tone discrimination during another (semantic-tone). In three subjects a third series was obtained alternating the semantic decision task with rest (semantic-rest). Active pixels were identified by correlating raw data with reference functions on a pixel-by-pixel basis [1]. Signal data from active pixels in the superior temporal gyrus (STG) and in the lateral frontal lobe of the left and right hemisphere were averaged to generate mean responses for each region.

Results

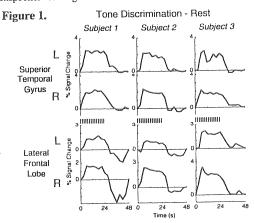
Fig. 1 illustrates averaged responses from three subjects during the *tone-rest* alternation. Signal increments were seen in the STG bilaterally, reflecting activation of auditory cortex during tone discrimination, with the signal returning to baseline during rest. Similar changes were observed in left and right frontal lobes (Fig. 1, bottom). When semantic and tone tasks were alternated, however, no signal fluctuation occurred in these same STG and right

frontal voxels (Fig. 2). In contrast, the left frontal lobe showed signal changes that were temporally correlated with the semantic task (Fig 2, bottom). Identical subtraction effects were observed in the other subjects. Data from the semantic-rest alternation demonstrated activation of the STG bilaterally in each of three subjects during the semantic task.

Conclusions

Elimination of the functional signal change in bilateral STG during the semantic-tone alternation occurred because these sensory areas were active during both tasks. Elimination of the functional signal change in right frontal cortex suggests that this region is also active during both tone discrimination and semantic decision tasks, possibly subserving general arousal and sustained attention functions [2]. Left lateral frontal cortex, in contrast, was more active during semantic decision than during tone discrimination, suggesting a specifically linguistic role for this brain region [3].

The task subtraction technique enables suppression of brain activity associated with selected functions. This selective suppression allows functional characterization of individual brain regions which may be activated as part of a large-scale, multi-component network. Task alternation also permits a description of the behavioral state at all times during an image series, which is not possible when a nonspecific "resting" state is used.



Semantic Decision - Tone Discrimination Figure 2. L Change Superior Temporal Gyrus R Tournment : հաստատ L Lateral Frontal Lobe R 24 24 Time (s)

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